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Fischer et al.

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(54) **SYSTEM AND METHOD FOR TRANSMITTING DATA**

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(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation of application No. 08/786,549, filed on Jan. 21, 1997, now Pat. No. 5,978,650.

(51) **Int. Cl.**[7] **H04N 7/173**

(52) **U.S. Cl.** **455/3.01**; 455/16; 455/22; 375/222; 348/14.01

(58) **Field of Search** 455/3.01, 5.2, 455/11.1, 16, 20, 22, 23, 93, 102, 426, 446, 447, 422; 375/211, 219, 220, 214, 216, 261, 281; 370/203, 206, 207, 14.01; 348/678

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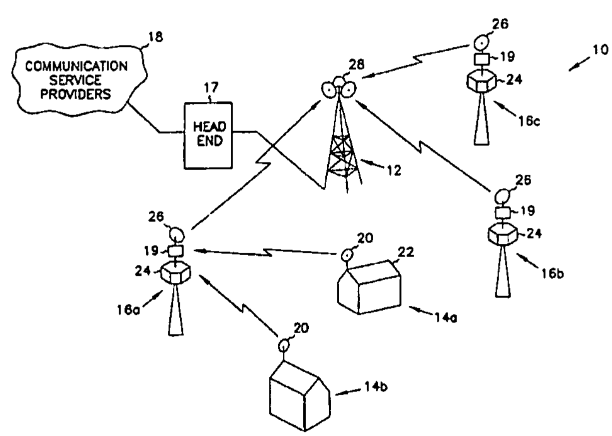
(74) *Attorney, Agent, or Firm*—Fogg Slifer & Polglaze, P.A.

(57) **ABSTRACT**

A transmission system (**10**). The transmission system communicates data to a number of subscribers (**14*a*, 14*b***). The transmission system includes a transceiver (**12**) that has a number of highly directional antennas (**28**). A number of digital repeaters (**16*a*, 16*b*, 16*c***) are disposed in a geographic region serviced by the transceiver. The repeaters include a sectorized antenna that communicates with subscribers in a number of sectors of the geographic region of the repeater. The repeater also includes an upstream demodulator/modulator circuit (**19**). The upstream demodulator/modulator circuit demodulates data from signals from subscribers that were modulated with a first modulation technique, and generates a re-modulated signal with the data using a second modulation technique. The second modulation technique is different from the first modulation technique such that the signals from the subscribers from the number of sectors are combined in the re-modulated signal so as to increase the capacity of the transmission system. The digital repeaters also include a highly directional antenna, that is coupled to the demodulator/modulator circuit and that communicates the re-modulated signal to the transceiver.

18 Claims, 10 Drawing Sheets



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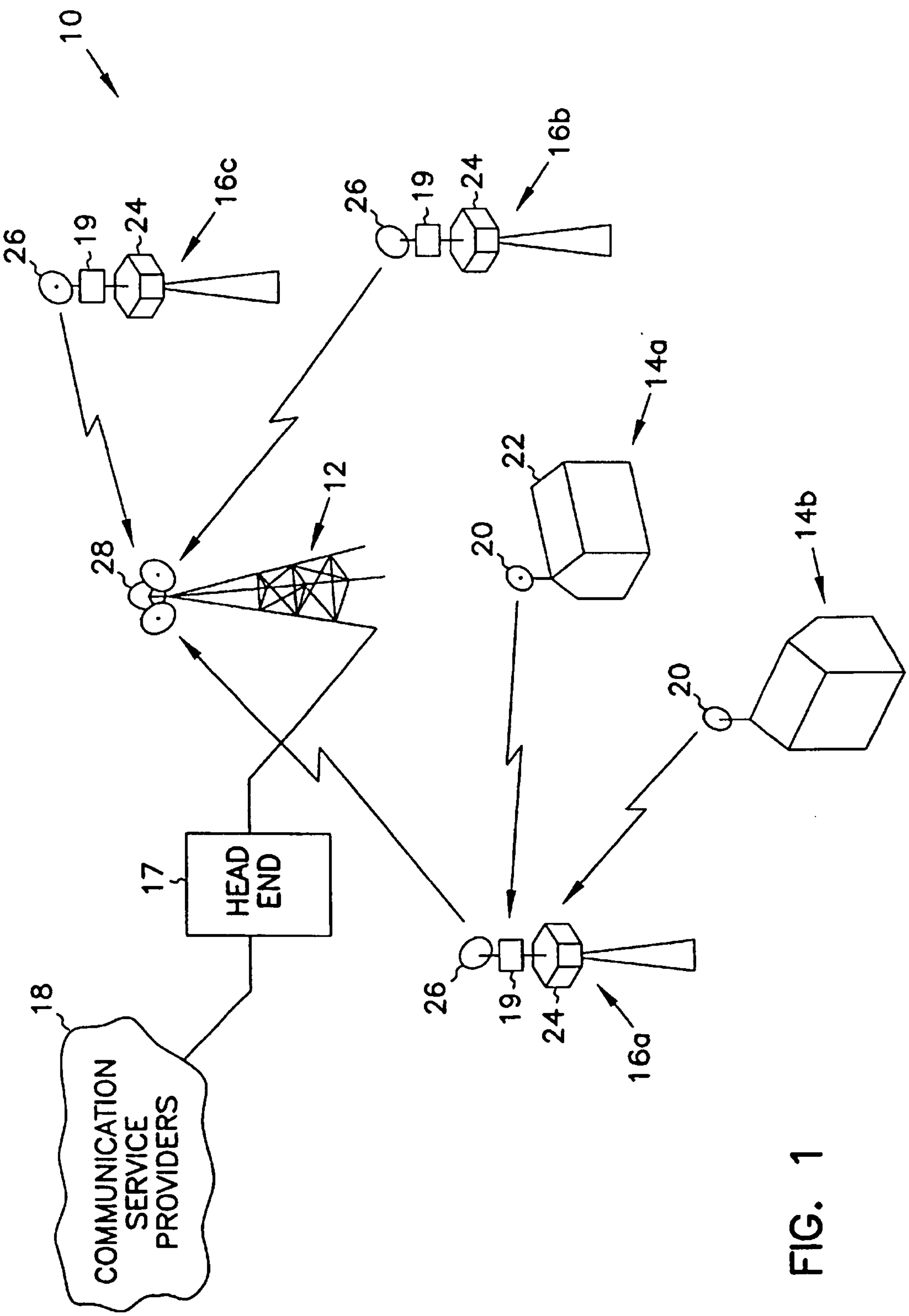

10
16c
26
19
24
26
19
24
16b
14a
22
12
28
20
14b
20
17
HEAD END
18
COMMUNICATION SERVICE PROVIDERS
26
19
24
16a

FIG. 1

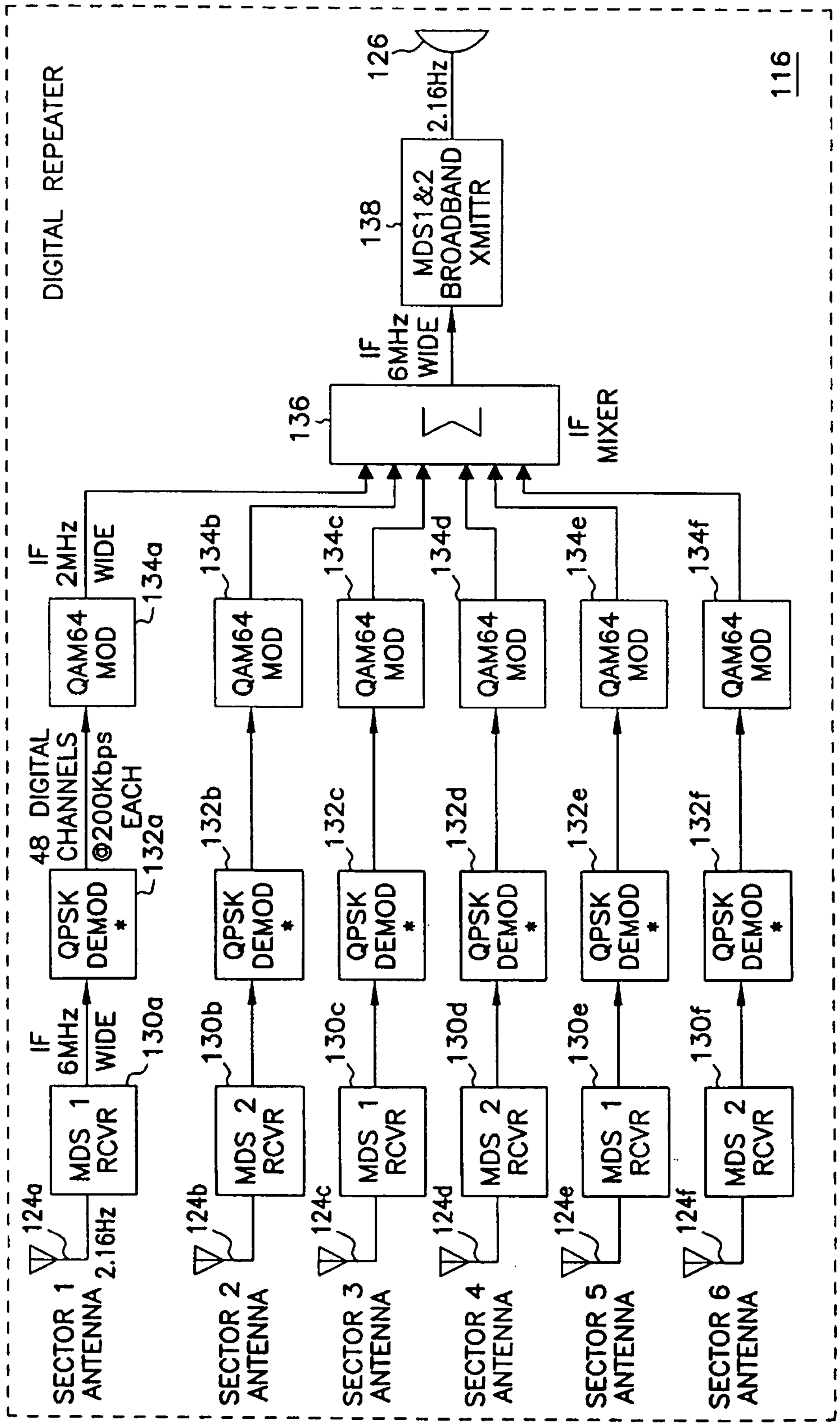

DIGITAL REPEATER
116
SECTOR 1 ANTENNA
SECTOR 2 ANTENNA
SECTOR 3 ANTENNA
SECTOR 4 ANTENNA
SECTOR 5 ANTENNA
SECTOR 6 ANTENNA
124a
124b
124c
124d
124e
124f
2.16Hz
MDS 1 RCVR
MDS 2 RCVR
MDS 1 RCVR
MDS 2 RCVR
MDS 1 RCVR
MDS 2 RCVR
130a
130b
130c
130d
130e
130f
IF 6MHz WIDE
QPSK DEMOD *
132a
132b
132c
132d
132e
132f
48 DIGITAL CHANNELS @200Kbps EACH
QAM64 MOD
134a
134b
134c
134d
134e
134f
IF 2MHz WIDE
136
IF MIXER
IF 6MHz WIDE
138
MDS1&2 BROADBAND XMITTR
2.16Hz
126

FIG. 2

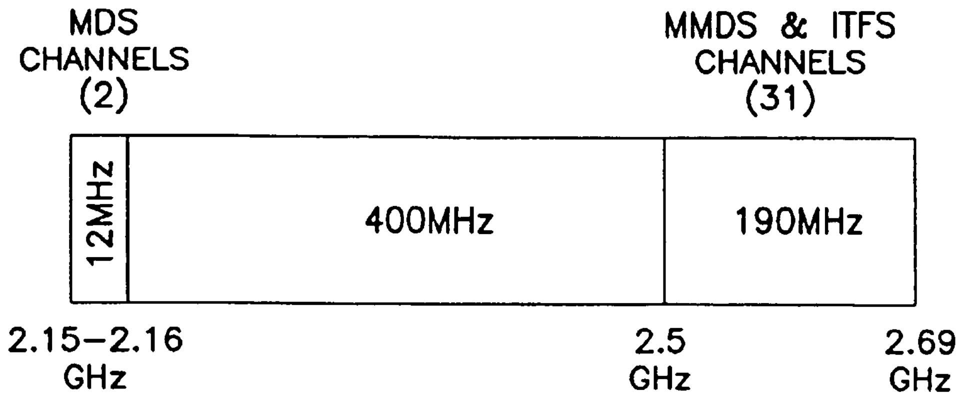

MDS
CHANNELS
(2)
MMDS & ITFS
CHANNELS
(31)
12MHz
400MHz
190MHz
2.15–2.16
GHz
2.5
GHz
2.69
GHz

FIG. 3

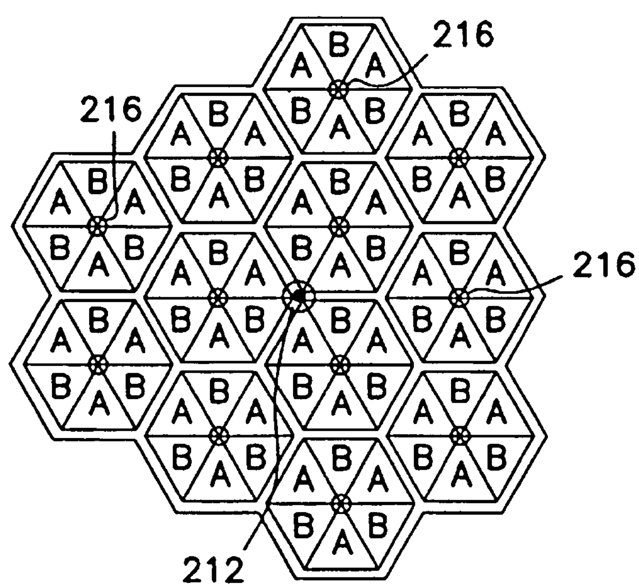

216
216
216
212

FIG. 4A

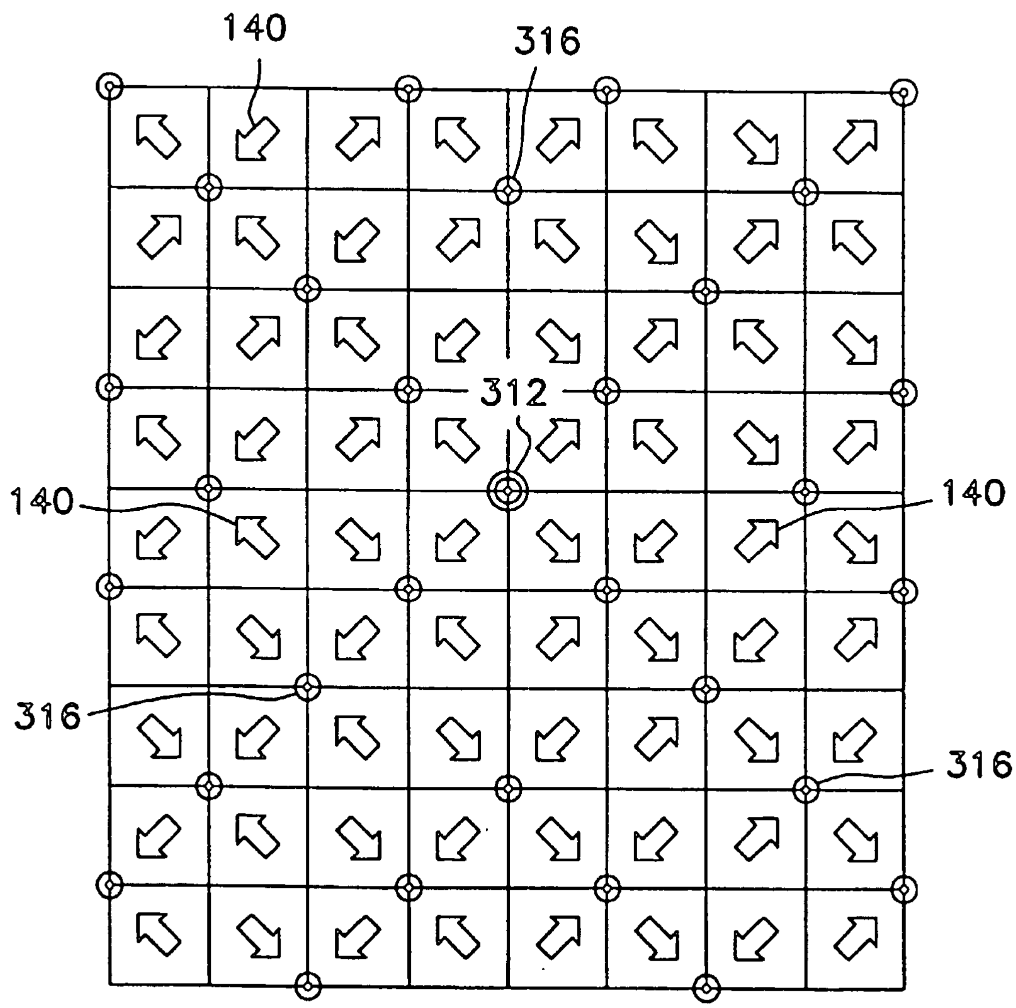


FIG. 4B

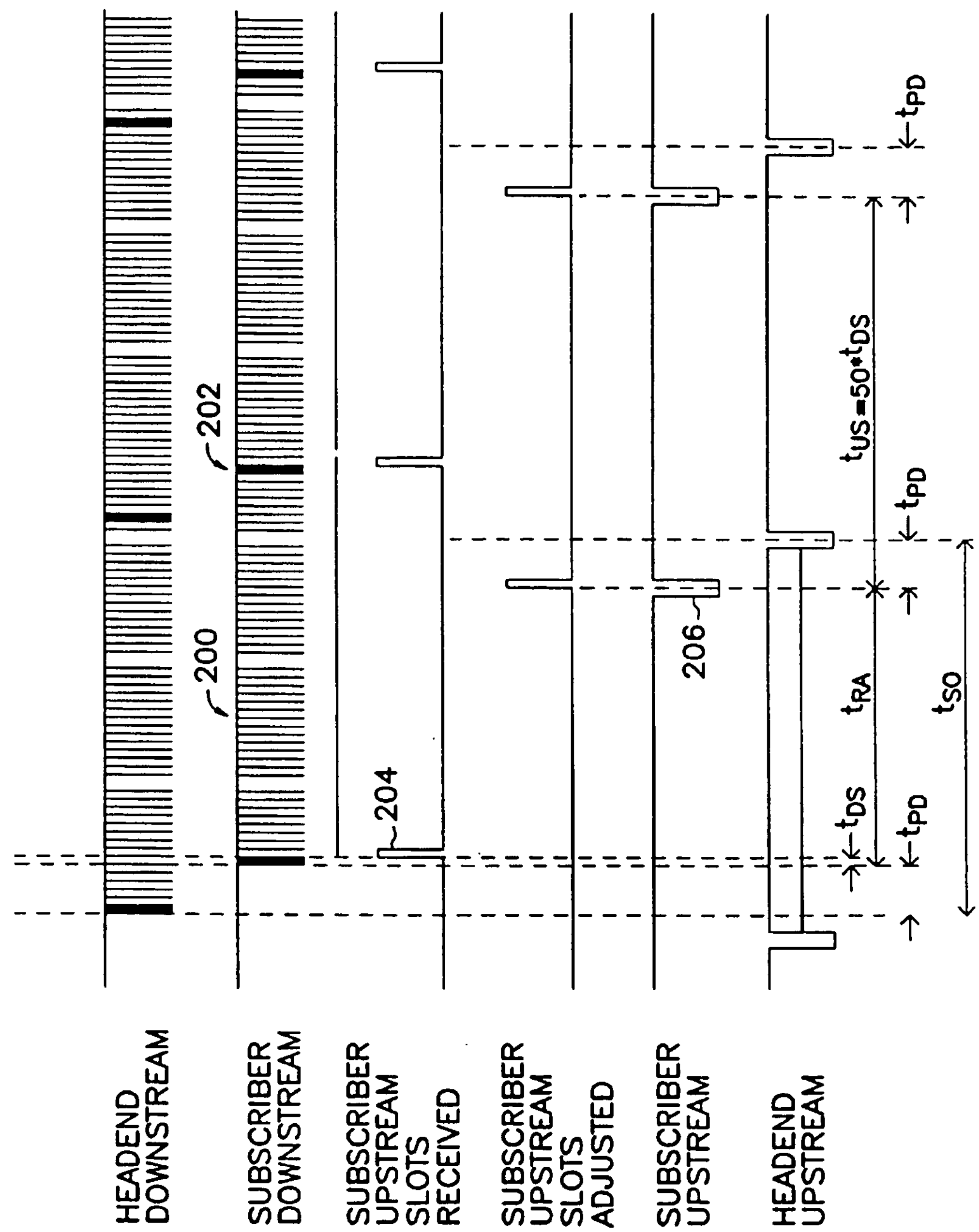


FIG. 5A

FIG. 5B

FIG. 5C

FIG. 5D

FIG. 5E

FIG. 5F

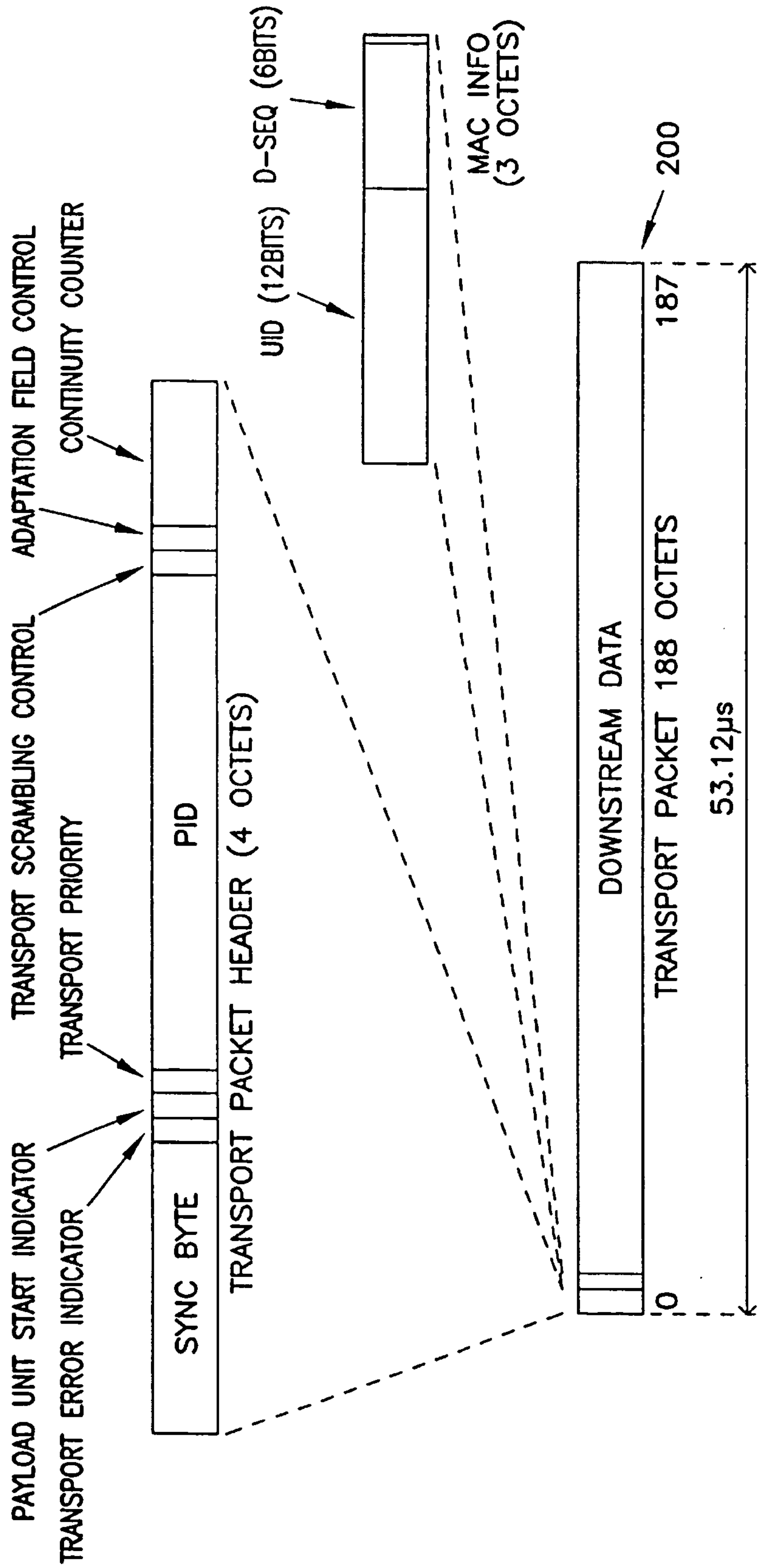
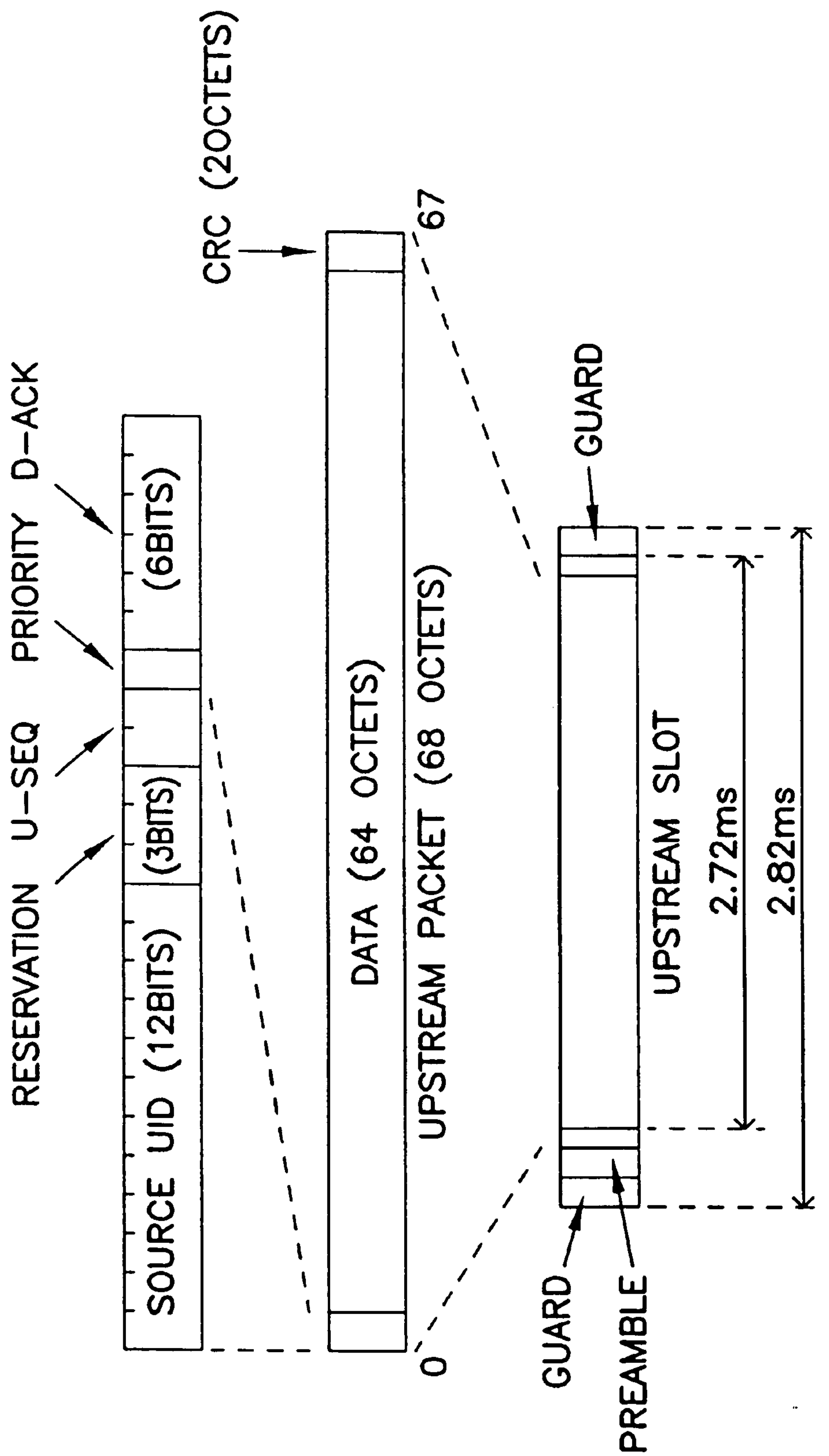

PAYLOAD UNIT START INDICATOR
TRANSPORT ERROR INDICATOR
TRANSPORT SCRAMBLING CONTROL
TRANSPORT PRIORITY
ADAPTATION FIELD CONTROL
CONTINUITY COUNTER
SYNC BYTE
PID
TRANSPORT PACKET HEADER (4 OCTETS)
UID (12BITS)
D-SEQ (6BITS)
MAC INFO
(3 OCTETS)
200
DOWNSTREAM DATA
0
187
TRANSPORT PACKET 188 OCTETS
53.12µs

FIG. 6



RESERVATION
U-SEQ
PRIORITY
D-ACK
SOURCE UID (12BITS)
(3BITS)
(6BITS)
CRC (2OCTETS)
DATA (64 OCTETS)
UPSTREAM PACKET (68 OCTETS)
67
0
GUARD
UPSTREAM SLOT
2.72ms
2.82ms
GUARD
PREAMBLE

FIG. 7

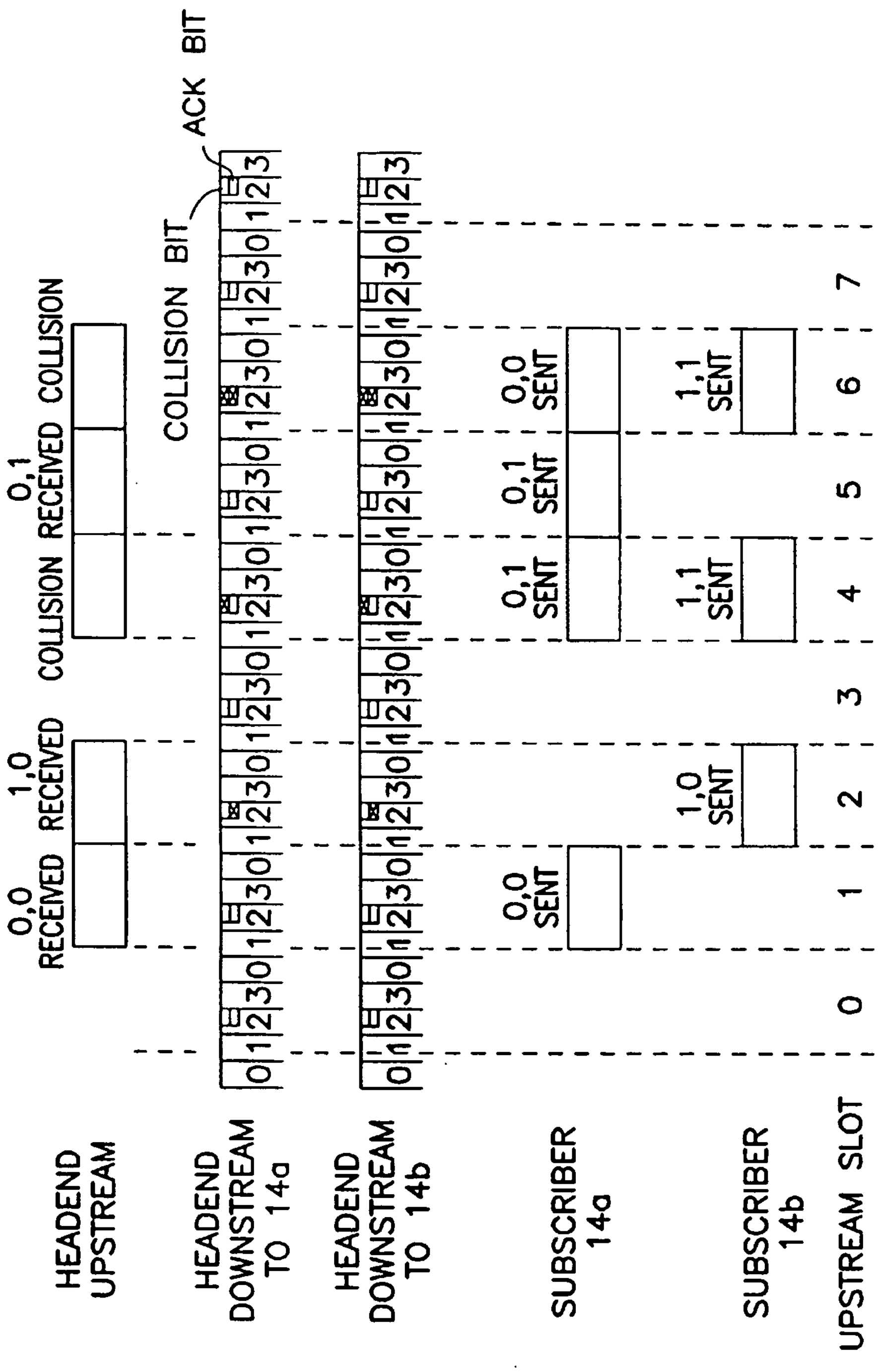


FIG. 8A

FIG. 8B

FIG. 8C

FIG. 8D

FIG. 8E

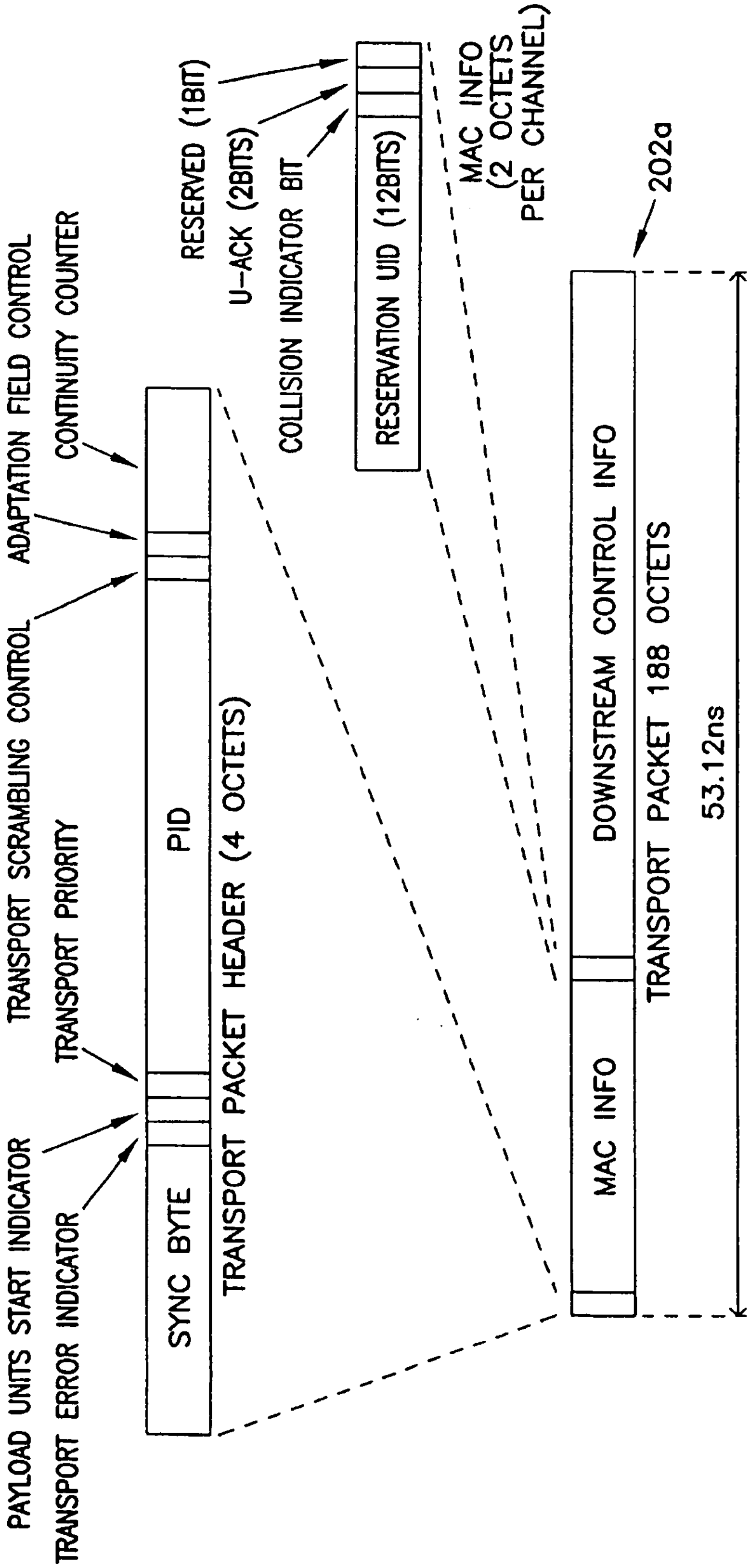

PAYLOAD UNITS START INDICATOR
TRANSPORT ERROR INDICATOR
TRANSPORT PRIORITY
TRANSPORT SCRAMBLING CONTROL
ADAPTATION FIELD CONTROL
CONTINUITY COUNTER
SYNC BYTE
PID
TRANSPORT PACKET HEADER (4 OCTETS)
RESERVED (1BIT)
U-ACK (2BITS)
COLLISION INDICATOR BIT
RESERVATION UID (12BITS)
MAC INFO
(2 OCTETS
PER CHANNEL)
202a
MAC INFO
DOWNSTREAM CONTROL INFO
TRANSPORT PACKET 188 OCTETS
53.12ns

FIG. 9

RESERVED (3BITS)

FORMAT TYPE (3BITS)

FIG. 10A

CHANNEL (6BITS)	UID (12BITS)			DATA (VARIABLE LENGTH)

GENERAL FORMAT OF DOWNSTREAM CONTROL INFORMATION. PACKET SIZE IS SYSTEM DEPENDENT

FIG. 10B

CHANNEL (6BITS)	UID (12BITS)	000	000	RECEVIED POWER AND CHANNEL SELECT

FORMAT FOR POWER CONTROL AND RANGING

FIG. 10C

CHANNEL (6BITS)	UID (12BITS)	001	000	CONDITIONAL ACCESS KEY

FORMAT FOR CONDITIONAL ACCESS KEY DOWNLOAD

FIG. 10D

CHANNEL (6BITS)	UID (12BITS)	010	000	DATA (VARIABLE LENGTH)

FORMAT FOR ETHENET PACKET

SYSTEM AND METHOD FOR TRANSMITTING DATA

This application is a continuation of U.S. Ser. No. 08/786,549 filed Jan. 21, 1997, now U.S. Pat. No. 5,978,650.

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to the field of telecommunications and, in particular, to a system and method for transmitting data.

BACKGROUND OF THE INVENTION

Consumers have an insatiable appetite for information and entertainment, colloquially referred to as "content." This can be seen in the popularity of television, the internet and other content based media that are delivered to subscribers or users over various "pipelines." A pipeline is a system that transmits data from a content provider, e.g., television station, website on the internet, etc., to a subscriber. For example, internet service providers such as AmericaOn Line use the telephony system as a pipeline to transmit information to its subscribers. The subscribers use a computer modem to dial-in to an internet service provider. Once on-line, the subscribers have access to various content providers (websites) and can download or upload information. Unfortunately, this is often a slow and cumbersome technique for conveying large quantities of data because the telephony system has transmission speed and bandwidth limitations. Certain subscribers have installed specialized high-speed telephonic connections, but the practice is not widespread because of the prohibitive costs.

Similarly, various conventional pipelines deliver video information from content providers with varying degrees of success. Conventionally, television stations use a wireless pipeline for delivering content to users. The television stations simply broadcast signals in a dedicated portion of the electromagnetic spectrum. Users access the signals with roof-top antennas. Cable systems are also used in many areas. These systems use coaxial cable to deliver video with increased quality and quantity directly to a user's home or premises. However, conventional cable systems do not allow for interactive feedback to the content providers over the cable system. Retrofitting the existing cable systems with this feature will be expensive and time consuming.

In recent years, the industry has developed another broadcast based pipeline for delivering video data to end users. This system is commonly referred to as "wireless cable." Wireless cable transmits microwave signals to subscribers from a central transmitter. The subscribers receive the signals with a microwave antenna that is placed on the roof-top of the subscriber's premises and aimed at the central transmitter.

A main drawback to the wireless cable systems is that there is a limited frequency spectrum that is available. Further, consumers desire to have access to interactive services over this pipeline. Some wireless cable systems have dabbled with providing two-way communication over their wireless cable systems. However, developers are left with the task of increasing the capacity of this pipeline by more efficiently using the limited spectrum that is available.

For the reasons stated above, and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for a transmission system that efficiently uses the assigned spectrum and allows for bidirectional communication.

SUMMARY OF THE INVENTION

The above mentioned problems with transmission system and other problems are addressed by the present invention and which will be understood by reading and studying the following specification. A transmission system is described which provides a more efficient use of assigned spectrum while allowing bi-directional communication.

In particular, an illustrative embodiment of the present invention provides a transmission system that communicates data to a number of subscribers. The transmission system includes a transceiver that has a number of highly directional antennas. A number of digital repeaters are disposed in a geographic region serviced by the transceiver. The repeaters include a sectorized antenna that communicates with subscribers in a number of sectors of the geographic region of the repeater. The repeater also includes an upstream demodulator/modulator circuit. The upstream demodulator/modulator circuit demodulates data from signals from subscribers that were modulated with a first modulation technique, and generates a re-modulated signal with the data using a second modulation technique. The second modulation technique is different from the first modulation technique such that the signals from the subscribers from the number of sectors are combined in the re-modulated signal so as to increase the capacity of the transmission system. The digital repeaters also include a highly directional antenna, that is coupled to the demodulator/modulator circuit and that communicates the re-modulated signal to the transceiver.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a representational diagram of an illustrative embodiment of a transmission system according to the teachings of the present invention;

FIG. 2 is a block diagram that illustrates an embodiment of an upstream communication portion of an rf repeater for use in the transmission system of FIG. 1;

FIG. 3 is a spectral diagram that illustrates a portion of the electromagnetic spectrum that embodiments of the present invention may use for upstream and downstream transmissions;

FIGS. 4A and 4B are schematic diagrams of exemplary spatial distributions of a number of digital repeaters in embodiments of the transmission system of FIG. 1 that form various cellular layouts;

FIGS. 5A through 5F are timing diagrams that illustrate embodiments of data transmission in a transmission system;

FIG. 6 is a diagram that illustrates an embodiment of the frame format of downstream data packets;

FIG. 7 is a diagram that illustrates an embodiment of the format of upstream data frames;

FIGS. 8A through 8E are timing diagrams that illustrate an embodiment of a collision detection method in upstream communications;

FIG. 9 is a diagram that illustrates an embodiment of downstream acknowledgment frames; and

FIGS. 10A through 10D are diagrams that illustrate embodiments of a command format for control frames for downstream communications in a transmission system according to the teachings of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of the preferred embodiments, reference is made to the accompanying draw-

ings which form a part hereof, and in which is shown by way of illustration specific illustrative embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

FIG. 1 is a representational diagram of an illustrative embodiment of a transmission system, indicated generally at **10**, according to the teachings of the present invention. Transmission system **10** provides for bi-directional transmission of data between central hub **12** and a number of subscribers. Central hub **12** is also referred to as a transceiver due to the bidirectional nature of its operation. Transmission system **10** may include a number of central hubs **12**. In FIG. **1**, subscribers **14***a* and **14***b* are shown for sake of clarity and illustration only. It will become clear from this specification, that transmission system **10** is designed to operate with a much larger number of subscribers on the order of 10,000 to 200,000 subscribers per central hub **12**. Thus the subscribers of system **10** are generically referred to as "subscribers **14**."

Transmission system **10** can transmit audio, video, or other data for use by a computer, a television, a telephone or other appropriate terminal of subscribers **14**. Transmission system **10** provides a pipeline between communication service providers **18** and subscribers **14**. Communication service providers **18** may, for example, provide services such as video, interactive video, internet connection, telephony or access to other content based services. Transmission system **10** includes head end **17** coupled between communication service providers **18** and central hub **12**. Head end **17** can communicate with communication service providers **18** and central hub **12** over any appropriate communication link such as wireless, including satellite and microwave or wired communication link as shown in FIG. **1**. Transmission system **10** further includes a number of digital repeaters, represented here by digital repeaters **16***a* through **16***c*. It is understood that transmission system **10** includes an appropriate number of digital repeaters referred to collectively as "digital repeaters **16**."

Digital repeaters **16** are spatially distributed in a geographic region to form a cellular-type layout. Use of a cellular approach allows frequency re-use to increase the spectrum efficiency of transmission system **10**. Subscribers **14** that communicate through different digital repeaters **16** can use the same frequency at the same time. Exemplary embodiments of cellular layouts are described below with respect to FIGS. **4**A and **4**B.

In the embodiment of FIG. **1**, transmission system **10** transmits digital data using the portions of the frequency spectrum currently licensed in the United States for analog multichannel multipoint distribution systems (MMDS), multipoint distribution systems (MDS) and instructional television fixed services (ITFS), as shown in FIG. **3**. Specifically, transmission system **10** uses the two MDS channels for upstream communication and the 31 MMDS and ITFS channels for down stream communication. These channels are specified as standard 6 MHz video channels as used in conventional analog video transmission. The two upstream channels occupy the spectrum between 2.15 and 2.16 GHz and the 31 downstream channels occupy the spectrum between 2.5 and 2.69 GHz. In one embodiment, five of the 31 downstream channels are reserved for data transmission such as for connection to the internet and the remaining twenty-six channels are reserved for video transmission such as commercial or pay television channels.

Transmission system **10** uses packets of digital data to increase the number of effective channels of the system. Specifically, transmission system **10** uses MPEG compression so as to transmit as many as 6 video channels in one 6 MHz channel. Similarly, transmission system **10** transmits multiple data channels in a single 6 MHz channel.

For upstream communication, transmission system **10** uses highly directional transmission between subscriber **14** and digital repeater **16** and between digital repeater **16** and central hub **12**. Advantageously, this allows transmission system **10** to more efficiently use the available electromagnetic spectrum by using the same two MDS 6 MHz transmission channels for transmissions between subscribers **14** and digital repeaters **16** and between digital repeaters **16** and central hub **12**.

Each subscriber **14** includes cardioid antenna **20** that is directed at an assigned digital repeater **16**. Cardioid antenna **20** is disposed at an elevation sufficient to allow line-of-sight transmission to repeater **16**. Typically, cardioid antenna **20** is disposed between 2 and 10 feet above roof **22** of subscriber **14**.

Further, digital repeater **16** includes antenna **24** and cardioid antenna **26**. Antenna **24** may, for example, be a sectorized antenna to divide a cell into as many as six sectors. For example, FIG. **4**A is a schematic diagram that shows a cellular layout wherein the cell boundaries are designated by a double line and sector boundaries within a cell are designated by a single line. It is understood that this is an idealized hexagonal cellular layout and that in practice the cells will overlap and have irregular shapes due to the terrain and other factors known to those skilled in the art. Other cellular and sectorization schemes may be used substituted as known to a person of ordinary skill in the art. Each sector is assigned to one of the two MDS 6 MHz channels such that adjacent sectors use different upstream channels. As shown in FIG. **4**A, for example, the sectors labeled "A" use channel MDS1 to communicate with digital repeaters **216** and the sectors labeled "B" use channel MDS2. This produces a three-times frequency re-use and further reduces the risk of interference being introduced into the transmissions from subscribers **14**. To further isolate adjacent sectors and reduce potential interference, alternating sectors could use different polarization. For example, the sectors could alternate between left and right circular polarization, horizontal and vertical polarization or other appropriate polarizations.

Cardioid antenna **26** is disposed so as to direct transmissions at central hub **12**. Cardioid antenna **26** is disposed at an elevation approximately six feet or more above antenna **24** so as to reduce potential interference between transmissions from subscribers **14** and transmissions to central hub **12** since these transmissions can use the same MDS channels. Potential interference could further be reduced by varying the polarization of the transmissions to and from digital repeater **16**. For example, in one embodiment subscribers **14** transmit signals with left hand circular polarization and digital repeater **16** transmits signals to central hub **12** with right hand circular polarization, or vice versa. Alternatively, vertical and horizontal polarization could be used. Central hub **12** includes at least one cardioid antenna **28** for each digital repeater **16**. To further reduce the potential interference and improper signals being received by central hub **12**, digital repeaters **16** can be positioned such

that subscribers 14 do not transmit toward central hub 12. Such a layout is shown in FIG. 4B using 90 degree sectors. In this embodiment, arrows 140 are situated to indicate the digital repeater 316 used by subscribers in each cell to communicate with central hub 312. This approach is equally applicable to sectorization techniques with other numbers of sectors. The key is to assign subscribers to a digital repeater such that the transmissions to the digital repeater are not aimed at the central hub.

For upstream communications, each MDS 6 MHz channel is divided into 48 narrowband transmission channels. The narrowband transmission channels have a bandwidth of 100 kHz and separation of 125 kHz. Subscribers 14 use quadrature phase shift keying (QPSK) modulation, for example, which accommodates two bits of data for each hertz of bandwidth. Thus subscribers 14 can transmit data at a rate of 200 kilobits per second (kbps). It is noted that transmission system 10 can further increase the number of available channels by using a 1 to 4 time division multiplexing technique to allow four users to share one 100 kHz channel.

QPSK modulation allows effective communication at low power. In transmission system 10, subscribers 14 typically will transmit at low power due to financial constraints on transmission equipment for subscriber 14. Further, the limited elevation of cardioid antenna 20 results in attenuation of power in signals from subscriber 14 due to ground effects and other interference. Thus, QPSK is an acceptable modulation technique for this low power transmission. Other modulation techniques which provide for robust transmission at low power levels could similarly be used.

Since each MDS 6 MHz channel is used by three sectors in this embodiment, transmission system 10 uses a different modulation technique to transmit between digital repeaters 16 and central hub 12. This allows the same two MDS 6 MHz channels to be re-used and carry up to three times the information as the MDS channels carried between subscribers 14 and digital repeaters 16. To accomplish this, digital repeaters demodulate the transmissions from subscribers 14 and use a quadrature amplitude modulation technique with 64 points in the constellation (QAM 64) to generate the signals to be transmitted to central hub 12. QAM 64 accommodates six bits per hertz of bandwidth as opposed to the two bits for QPSK, thus this produces the needed three-fold increase in spectral efficiency. Further, each MDS 6 MHz channel is divided into 144 sub-channels of 33.3 kHz with 41.7 kHz of separation for transmissions from digital repeater 16 to central hub 12. Transmissions from digital repeater 16 to central hub 12 are not as susceptible to ground effect attenuation or other forms of interference. Thus, a less robust modulation technique such as QAM 64 can be used. It is understood that other modulation techniques that provide for the re-use of frequencies in the different sectors can be used in place of QAM 64.

In operation, transmission system 10 transmits upstream communications from subscribers 14 to communication service provider 18 through central hub 12. For example, subscriber 14a modulates a carrier with data using a QPSK modulation technique. Subscriber 14a transmits this signal with cardioid antenna 20. Digital repeater 16a receives signals from subscribers including subscriber 14a with antenna 24. Digital repeater 16a demodulates the signals from the subscribers and re-modulates the signals using QAM 64 modulation. Digital repeater 16a transmits the re-modulated signals to central hub 12. Central hub 12 transmits the signals to communication service provider 18 through head end 17. Similarly, transmission system 10 also transmits data downstream to subscribers 14. To accomplish this, transmission system 10 can use the same antennas or can include a separate set of antennas for downstream transmission.

FIG. 2 is a block diagram of an embodiment of the upstream communication of a digital repeater, indicated generally at 116, and constructed according to the teachings of the present invention. It is understood that digital repeater 116 includes appropriate circuitry for transmitting downstream data to subscribers 14. Digital repeater 116 includes sector antennas 124a through 124f that are coupled to receivers 132a through 132f, respectively. Receivers 130a, 130c, and 130e are tuned to the first MDS 6 MHz channel. Further, receivers 130b, 130d, and 130f are tuned to the second MDS 6 MHz channel. Receivers 130a through 130f are coupled to QPSK demodulators 132a through 132f, respectively. Further, QPSK demodulators 132a through 132f are coupled to QAM 64 modulators 134a through 134f. The output of each QAM 64 modulator is coupled to IF mixer 136. The output of IF mixer 136 is coupled through broadband transmitter 138 to cardioid antenna 126.

In operation, digital repeater 116 receives signals from subscribers 14 and changes the modulation of the signals so as to efficiently use the electromagnetic spectrum reserved for upstream communications. For example, subscriber in sector 1 transmit signals that are received at antenna 124a and receiver 130a. The output of receiver 130a is supplied to QPSK demodulator 132a as a 6 MHz band of signals. QPSK demodulator 132a demodulates the signals from the subscribers in sector 1 to produce 48 digital channels of 200 kbps each. QAM 64 modulator 134a generates a signal with a 2 MHz bandwidth from the output of QPSK demodulator 132a using QAM 64 modulation of the 48 digital channels. IF mixer 136 combines the signal from QAM 64 modulator 134a with similar signals from QAM modulators 134b through 134f to produce a signal with a 12 MHz bandwidth. Broadband transmitter 138 upconverts, amplifies, filters and transmits the signal to central hub 12 with cardioid antenna 126.

In one embodiment, transmission system 10 of FIG. 1 is controlled by a media access control (MAC) protocol. The MAC protocol supports video-on-demand services, data services, and control functions. The MAC protocol is an asymmetric protocol which uses fixed size MPEG 13818-1 transport stream transport packets for downstream transmissions and short, fixed size slots for upstream transmission. The protocol is consistent with DAVIC Technical Specifications 1.2 for MMDS by using transport packets for downstream. DAVIC presently leaves the upstream undefined ("reserved"). The MAC protocol of this embodiment is described in conjunction with FIGS. 5A through 10.

The downstream protocol is based on a single high speed (27 Mbps) channel which contains data packets for many users and provides reliable packet delivery using automatic repeat request (ARQ). The downstream link protocol used is based on the GoBackN protocol with N set to 4 (i.e., 2 bits). The upstream protocol is a slotted collision detect protocol distributed over many low speed (200 Kbps) channels with explicit acknowledgment of packets. Again, the ARQ protocol used is GoBackN, with N set to 64 (i.e., 6 bits). The upstream bandwidth is also managed by a bandwidth reservation system controlled by headend 17. This system permits headend 17 to reserve upstream slots for particular subscriber 14 and is used to improved protocol efficiency. The complete protocol is designed to be simple and flexible, yet efficient.

FIGS. 5A through 5F are timing diagrams that illustrate embodiments of data transmission in transmission system 10

of FIG. 1. A definite timing relationship is maintained between the downstream and upstream packets, e.g., 50:1 in this embodiment. Downstream packet sizes are 188 bytes at a data throughput rate of 27 Mbps. Upstream slots are 68 bytes with additional preamble and guards to maintain the correct ratio.

Downstream packet delivery is composed of two types of MPEG-2 transport packets, data transport packets and acknowledgment transport packets. Data transport packets are identified by a unique packet identification (PID) and acknowledgment transport packets are identified by a different unique PID. As illustrated in FIGS. **5A** and **5B**, the downstream data stream is composed of a sequence of 50 data transport packets **200** followed by an acknowledgment transport packet **202**.

FIG. **5A** illustrates the downstream packet sequence generated by headend **17**. Each slot in the downstream takes one downstream slot time (t_{DS}) to be transmitted. FIG. **5B** shows a propagation delay (t_{PD}) from the transmission of the acknowledgment packet to the arrival of the first bit of the acknowledgment packet at subscriber **14**. FIGS. **5C** and **5D** illustrate that once the entire packet has been received, subscriber **14** uses the packet as a timing mark **204** and delays transmitting on the upstream for ranging adjustment (t_{RA}). FIG. **5E** shows that if the subscriber has any data to transmit and the slot has not been reserved as described below, the subscriber may attempt to send an upstream packet **206**. FIG. **5F** illustrates a propagation delay (t_{PD}) from the transmission of the first bit of the upstream packet to the arrival of the upstream packet at headend **17**. Because the upstream slot size is determined by a fixed ratio (e.g., 50:1), the time to transmit the upstream slot, i.e., upstream slot time (t_{US}) is defined by $50 \times t_{DS}$.

The ranging adjustment time (t_{RA}) is set for each subscriber **14** so that upstream slots from all subscribers arrive at headend **17** at the same time. This ensures that either a packet is received by headend **17** during the fixed slot time or one or more packets collide in a synchronized manner at headend **17**. In the case in which collision occurs, all packets are assumed to be lost. Packet collision is detected by a failure to recognize a packet and is aided by using a cyclic redundancy check (CRC).

FIG. **6** is a diagram that illustrates the frame format of the downstream data packets **200**. The basic form of the packet is an MPEG 13818-1 transport packet of fixed size (e.g., 188 bytes) and contains a 4 byte header. In general, transport packet PIDs are used to indicate program content including video and audio streams. In order to prevent any conflict with video programming the PID field is used only in the most limited manner. Specifically, two PIDs are used, one to indicate "normal" downstream data and the other for downstream acknowledgment.

The MAC protocol includes two additional fields that immediately follow the transport header field and are as follows:

1) The User Identification (UID) field is 12 bits. Each subscriber **14** is assigned a unique UID number for the channel in which it resides. The UID is used in all dialogues between headend **17** and the subscriber **14**. There will typically be a mapping between the UID and other subscriber identification numbers, e.g., Ethernet MAC address, IP address, or subscriber billing number. The UID has a context only between headend **17** and subscriber **14** and should be otherwise transparent. If a subscriber **14** is reassigned to a new channel (as may happen as system load increases) the subscriber **14** will receive a new UID.

2) The Downstream Sequence Number (D-Seq) field is 6 bits. The D-Seq field is used to permit multiple unacknowledged frames to be maintained in a transmission buffer for the subscriber **14**. The protocol used with the D-Seq field is GoBackN.

FIG. **7** is a diagram that illustrates the format of upstream data frames **206**. The frame length is defined to be some integer number of downstream packets and is synchronized to the downstream packet rate. For this embodiment the ratio is 50:1.

The fields in the upstream frame format are as follows:

1) The guard field contains a variable number of bits that are used to provide space between slots.

2) The preamble field contains 16 bits, 01010101 01111110, that are used to synchronize the incoming packet at headend **17**.

3) The source UID is 12 bits that indicate the source user identification number.

4) The reservation field is 3 bits that provide reservation information as described in more detail below.

5) The Upstream Sequence Number (U-Seq) filed is 2 bits that permit multiple unacknowledged frames to be maintained in a transmission buffer of headend **17**. The protocol used with the U-Seq field is GoBackN.

6) The priority field is 1 bit that indicates the message priority to headend **17**.

7) The D-ACK field is a 6 bit acknowledgment field that is used by the MAC layer of headend **17** to identify when a downstream data packet is out of sequence. The protocol used (in conjunction with the D-SEQ field) is GoBackN.

8) The data field is 64 bytes.

9) The cyclic redundancy check (CRC) field is a 16 bit field that permits headend **17** to identify when an incoming packet is in error. In one embodiment CCITT-16 is used.

FIGS. **8A** through **8E** are timing diagrams that illustrate an embodiment of a collision detection method in upstream communications for the MAC protocol. This method provides an efficient mechanism for ensuring that subscribers **14** are aware when a collision has taken place. As described above, there is exactly one downstream acknowledgment packet in each upstream slot time. This packet is timed to be delivered somewhere in the middle of the upstream slot time (although this time reference will vary depending on the distance of the subscriber from headend **17**) and is used to provide a collision detection function for each of the upstream slot times. Thus by inspecting the downstream collision indication in the slot immediately following an upstream transmission, subscriber **14** is able to determine if an upstream packet was received by headend **17**.

FIGS. **8B** and **8C** show the use of a single acknowledge (ACK) and collision bit as they relate to two subscribers **14a** and **14b**, respectively, on the same channel. The ACK and collision bits form part of the downstream acknowledge packet. This packet includes bits for all channels as discussed below. The ratio between up and downstream slots is only 4 for illustrative purposes.

FIGS. **8D** and **8E** show transmissions from subscribers **14a** and **14b**, respectively. FIG. **8A** shows the result at headend **17**. FIGS. **8B** and **8C** show headend **17** transmission with embedded acknowledgments and collision notifiers.

Upstream slot **0** shows neither subscriber using the channel. Upstream slot **1** shows subscriber **14a** sending a frame (i.e., frame 0,0). Upstream slot **2** shows subscriber **14b**

sending a frame (i.e., frame 1,0) and subscriber **14a** receiving an ACK indicating frame 0,0 was received by headend **17** without collision. Upstream slot **3** shows neither station using the channel, however, subscriber **14b** receives an ACK for frame 1,0. Upstream slot **4** shows both subscribers **14a** and **14b** attempting to send data. A collision occurs and both stations are made immediately aware of the situation via the downstream collision indication bit. Upstream slot **5** shows subscriber **14a** sending a frame. Upstream slot **6** shows subscribers **14a** and **14b** attempting to send another frame. A collision occurs which both stations are made immediately aware of. In addition, subscriber **14a** receives an ACK indicating frame 0,1 was received correctly.

FIG. **9** is a diagram that illustrates an embodiment of a downstream acknowledgment frame, indicated generally at **202a**, for the MAC protocol. The acknowledgment frame **202** is identified by a PID in the transport packet header, e.g., PID=2. The frame is divided into two parts, a "MAC Info" part and a "Control Info" part.

The MAC Info part of the frame is used for MAC protocol collision and acknowledgment for each of the downstream channels under control by headend **17** as described above. Thus, each upstream channel is mapped into a particular pair of bytes in the MAC Info part. The first pair of bytes corresponds to channel 0, the second pair to channel 1, and so on. The two-byte Mac Info for each channel contains the following fields:

1. The Reservation UID field is 12 bits. The reservation UID is used by the downstream to indicate which UID is permitted to use the next upstream slot on that channel. Details of the reservation mechanism are discussed below.
2. The Collision Indicator field is 1 bit. This bit indicates when a collision has occurred.
3. The User Acknowledgment (U-ACK) field is 2 bits. The U-ACK field is used by the subscriber MAC layer to identify when an upstream data is out of sequence. The protocol used (in conjunction with the U-SEQ field) is GoBackN. This field is similar to the ACK field as described above.
4. The Reserved field is 1 bit.

FIGS. **10A** through **10D** are diagrams that illustrate embodiments of a command format for control frames for downstream communications in a transmission system according to the teachings of the present invention. Specifically, FIGS. **10A** through **10D** illustrate various embodiments of the Control Info part of transport packets **202a** of FIG. **9**. The Control Info part is used for downstream control information (e.g., for system configuration, ranging, power control, and conditional access keys) and as a downstream for the Video On Demand (VOD) control services. However, the channel may also be used for downstream data services.

In FIGS. **10A** through **10D** the following fields are common:

1. The Channel field is 6 bits. The field indicates the channel to which this downstream control packet refers. Each Subscriber Unit is in one and only one channel, thus, if the Channel number and UID match, the packet is destined for this subscriber unit.
2. The User Identification (UID) field is 12 bits.
3. The Format Type field is 3 bits. A number of different frame formats are supported. The particular format to be decoded is identified by this field.
4. The Reserved field is 3 bits. The field indicates that the packet is reserved for future use.

In this embodiment, three acceptable formats are initially defined for the Format Type field. Format **000** is used for downstream ranging, power control, and UID assignment as shown in FIG. **10B**. Format 001 is used for downstream conditional access key download as shown in FIG. **10C**. The conditional access key is transmitted with the packet and is used to enable the subscriber to receive a particular video channel (as identified by the transport PIDs). Format 010 is used to convey downstream Ethernet packets as shown in FIG. **10D**. This can also be used for VOD services which require general data transfer capabilities. It is envisaged that the subscriber unit will have an Ethernet aware protocol stack for this environment. Other frame formats may be defined as required.

The reservation protocol used by the MAC protocol is extremely flexible and designed to permit maximum control of the bandwidth by headend **17**. Thus, the subscriber unit is kept as simple as possible.

Referring again to FIG. **9**, a Reservation UID is identified for each downstream channel. In each channel, this Reservation UID is used by headend **17** to indicate which subscriber **14** can transmit in the following upstream time slot. The protocol works as follows: Each time a subscriber **14** sends an upstream frame, it includes a three bit field to indicate the number of additional frames the unit still needs to transmit (0=0 frames, 7=7+frames).

If the frame from subscriber **14** is received (via the U-ACK), subscriber **14** must then wait to be allocated a slot by headend **17**, even if the channel is idle. Headend **17** maintains an estimate of the number of frames buffered by each subscriber **14** and uses this information to increase the upstream bandwidth utilization. Headend **17** may also track subscriber upstream data usage and demands, and constrain subscriber transmissions for appropriate sharing of the channel.

The scheduling policy for headend **17** is based on an assumption that the underlying traffic model is characterized by data bursts generated through either Near Video On Demand (NVOD) commands or web browsing traffic. In the event that the traffic characteristics changed, it is entirely possible to implement a new scheduling policy at headend **17** with no modification to subscribers **14**.

The current embodiment attempts to accommodate the transmission of a typical data burst from a subscriber unit. Assuming that the typical burst length is B slots, a logical construct called a macro-slot, which is an integer multiple of B, is used for scheduling. The upstream is considered a sequence of macro-slots. Each macro-slot is divided into two portions, a sequence of reservation slots and a sequence of contention slots. Subscribers **14** participating in the reservation process burst data during the reservation slots in a round robin fashion. The round robin algorithm is used to ensure fairness. At the end of each macro-slot headend **17** is responsible for using statistics obtained from the previous macro-slot (e.g., number of collisions, ratio of reserved slots to contention slots and number of successfully transmitted packets in the contention period) to determine the ratio of the next macro-slot. The algorithm used to compute the ratio presently increases the number of contention slots when the number of collisions is too high and decreases the number of contention slots when the number of collisions is too low. This approach increases the channel throughput.

In addition to scheduling there is a requirement to impose rate control on the traffic. The recommended algorithm for headend **17** is based on restricting the upstream (downstream) flow to subscriber units based on the leaky bucket traffic model and is outlined as follows:

1. Headend **17** maintains a bucket for each subscriber which corresponds to an average data rate as determined by simulation studies. At present this is expected to be 20 Kbps (384 Kbps) and is filled at this rate.
2. Whenever an upstream packet is received, the bucket is drained at 200 Kbps (1 Mbps).
3. If the bucket is not empty and the reservation bits indicate the subscriber has more data to transfer.

The above two algorithms are used to demonstrate how headend **17** may define the upstream and downstream protocols. The actual protocol to be used can be varied based on various system constraints.

In the event that it was deemed necessary to support a signaling plane between headend **17** and subscriber **14** for multiple services classes (e.g., isochronous services, etc.) there are at least two approaches possible:

1. A separate UID could be assigned to each subscriber **14** which is dedicated to signaling.
2. A single bit in the upstream packet could be used to distinguish user data from control data. A bit that is presently unused and could be used for this function is the priority bit.

By including this feature it would be possible to support a variety of provisioned services such as those defined in Asynchronous Transfer Mode (ATM) by appropriate modification of the upstream and downstream scheduling policies used in headend **17**. Such changes could be made transparent to previously deployed subscribers **14**.

Although the protocol is the same for both Video On Demand and Data it exhibits different characteristics as indicated below. In particular, it is expected that particular channels will be designated as upstream (downstream) data channels and others as upstream (downstream) Near Video on Demand channels (NVOD). Thus a subscriber unit will be assigned to one or the other but cannot be both (however, the flexibility of the protocol does not preclude accessing data from a NVOD channel or Videos from a data channel).

For data services, bandwidth allocation will typically be one downstream channel and 32 upstream channels. Most of the downstream Transport Packets will have PID either 1 or 2 and all subscribers **14** will be tuned to the same downstream channel (the system is scalable in the sense that the entire concept may be replicated on multiple downstream/upstream channel sets). The ACK packet (PID=2) must be transmitted every 50 transport packets in order for the upstream protocol to operate properly. Since the upstream bandwidth is significant, it is expected that many upstream channels will be assigned to data services and thus the number of channels represented in the downstream MAC Info field will be large (perhaps 32) leaving little room for the Control Info field.

For VOD services, each downstream channel will be composed mainly of Video and Audio Transport Packets, however, the ACK packet (PID=2) is always required. As before, the ACK packet (PID=2) must be transmitted once for every 50 transport packets in order for the upstream protocol to operate properly. In general, the ACK packet will be used to provide the MAC functions and limited control functions required for VOD services. With this in mind, it is likely that only a few upstream channels will be assigned to VOD services and these will be used to accommodate a large number of simultaneous users. Typically the number of channels represented in the downstream MAC Info field will be small (perhaps only 4) leaving correspondingly more space for the Control Information. This space may be used to transmit general purpose Ethernet packets downstream if required. The downstream data rate is limited to about 380 Kbps in this case unless additional data transport packets are sent.

Associated with the protocol will be a number of time-outs. These are used to improve the efficiency of the protocol but do not contribute to the basic protocol correctness. The essential time-outs required are as follows:

1. Upstream retransmission timer for each subscriber **14** is set whenever an upstream packet is sent by the subscriber. If there is no acknowledgment by headend **17** within some time limit the subscriber will retransmit the packet.
2. Upstream ack timer for each subscriber is set whenever a downstream packet is received by the subscriber unit. If no upstream data is received from the subscriber unit within some time limit the subscriber unit will send an acknowledgment packet (i.e., repeat the last upstream packet with the correct D-ACK field set).
3. Headend **17** unit downstream retransmission timer is set whenever a downstream packet is sent by headend **17**. If there is no acknowledgment by the within some time limit, headend **17** unit will retransmit the packet.

Other timers may be required to implement non-essential components of the protocol, e.g., support for the priority scheme. These are not described here.

The protocol also provides a limited facility for expedited data upstream. The priority field in the upstream packet is used by the subscriber to indicate to headend **17** that the data in the packet should be expedited. This information may be used or ignored by headend **17** depending on the upstream algorithm implemented in headend **17**.

Conclusion

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement which is calculated to achieve the same purpose may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. For example, the specific cellular layout can be varied from the four and six sector layouts shown in the Figures. Further, it is contemplated that other modulation techniques can be used in place of the QPSK and QAM 64 techniques so long as they provide adequate frequency re-use among the sectors in the upstream direction. Further, other types of antennas may be used that provide highly directional communication between the central hub and the digital repeaters and between the digital repeaters and the subscribers.

What is claimed is:

1. A method for upstream communication between a plurality of subscribers and a communication service provider over a transmission system, comprising:

receiving signals with a number of sectorized repeaters, wherein each repeater is adapted to receive signals from more than one subscriber, the signals being modulated with data using a first modulation technique;

demodulating the data from the signals;

generating re-modulated signals with the data from the subscribers using a second modulation technique that is different from the first modulation technique;

combining the re-modulated signals, thereby generating a re-modulated and combined signal; and

communicating the re-modulated and combined signal to a transceiver of the transmission system.

2. The method of claim 1, wherein demodulating the data from the signals comprises demodulating data from signals that were modulated using quadrature phase shift keying.

3. The method of claim 1, wherein generating re-modulated signals comprises generating re-modulated signals using quadrature amplitude modulation.

4. The method of claim 1, wherein generating the re-modulated signals comprises generating re-modulated signals using quadrature amplitude modulation with a 64 point constellation.

5. The method of claim 1, wherein receiving upstream signals comprises receiving upstream signals with a first polarization and wherein communicating the re-modulated signal comprises transmitting signals with a second, different polarization.

6. The method of claim 5, wherein the first polarization comprises left-hand circular polarization and the second polarization comprises right-hand circular polarization.

7. A method for upstream communication between a plurality of subscribers and a communication service provider over a transmission system, comprising:

receiving signals with a sectorized repeater from the plurality of subscribers, wherein the repeater receives first signals from a plurality of first subscribers using a first upstream channel and the repeater receives second signals from a plurality of second subscribers using a second upstream channel different from the first upstream channel, and wherein the first and second signals received by the repeater are modulated with data using a first modulation technique;

demodulating the data from the first and second signals;

re-modulating the data from the first and second signals using a second modulation technique that is different from the first modulation technique, thereby generating re-modulated signals;

combining the re-modulated signals, thereby generating a combined signal; and

communicating the combined signal to a transceiver of the transmission system.

8. The method of claim 7, wherein the first upstream channel is the multipoint distribution system channel MDS 1 and the second upstream channel is the multipoint distribution system channel MDS 2.

9. The method of claim 7, wherein the first signals use a first polarization and the second signals use a second polarization different from the first polarization.

10. The method of claim 7, wherein the second modulation technique has a higher spectral efficiency than the first modulation technique.

11. The method of claim 10, wherein the second modulation technique is quadrature amplitude modulation and the first modulation technique is quadrature phase shift keying modulation.

12. A sectorized digital repeater, comprising:

a first receiver tuned to receive first signals on a first communication channel from a first sector antenna, wherein the first signals are modulated with data using a first modulation technique;

a first demodulator coupled to receive the first signals from the first receiver and to demodulate the data from the first signals;

a first modulator coupled to receive the demodulated data from the first signals, wherein the first modulator uses a second modulation technique different from the first modulation technique to re-modulate the demodulated data from the first signals, thereby generating re-modulated first signals;

a second receiver tuned to receive second signals on a second communication channel from a second sector antenna, wherein the second signals are modulated with data using the first modulation technique;

a second demodulator coupled to receive the second signals from the second receiver and to demodulate the data from the second signals;

a second modulator coupled to receive the demodulated data from the second signals, wherein the second modulator uses the second modulation technique to re-modulate the demodulated data from the second signals, thereby generating re-modulated second signals;

an IF mixer coupled to receive and combine at least the re-modulated first and second signals into a combined signal; and

a broadband transmitter coupled to receive and transmit the combined signal from the IF mixer.

13. The sectorized digital repeater of claim 12, wherein the first communication channel is the multipoint distribution system channel MDS 1 and the second communication channel is the multipoint distribution system channel MDS2.

14. The sectorized digital repeater of claim 12, wherein the second modulation technique has a higher spectral efficiency than the first modulation technique.

15. The sectorized digital repeater of claim 14, wherein the second modulation technique is quadrature amplitude modulation and the first modulation technique is quadrature phase shift keying modulation.

16. The sectorized digital repeater of claim 12, further comprising:

a third receiver tuned to receive third signals on the first communication channel from a third sector antenna, wherein the third signals are modulated with data using the first modulation technique;

a third demodulator coupled to receive the third signals from the third receiver and to demodulate the data from the third signals; and

a third modulator coupled to receive the demodulated data from the third signals, wherein the third modulator uses the second modulation technique to re-modulate the demodulated data from the third signals, thereby generating re-modulated third signals;

wherein the IF mixer is further coupled to receive and combine the re-modulated third signals with the re-modulated first and second signals into the combined signal.

17. A sectorized digital repeater, comprising:

a first receiver for receiving first signals on a first communication channel from a first sector antenna, wherein the first signals are modulated with data using a first modulation technique;

a first demodulator for demodulating the data from the first signals;

a first modulator for re-modulating the demodulated data from the first signals into first re-modulated signals, wherein the first modulator uses a second modulation technique different from the first modulation technique;

a second receiver for receiving second signals on a second communication channel from a second sector antenna, wherein the second signals are modulated with data using the first modulation technique;

a second demodulator for demodulating the data from the second signals;

a second modulator for re-modulating the demodulated data from the second signals into second re-modulated signals, wherein the second modulator uses the second modulation technique;

an IF mixer for combining the first and second re-modulated signals into a combined signal; and

a broadband transmitter for amplifying, filtering and transmitting the combined signal from the IF mixer.

18. The sectorized digital repeater of claim 17, further comprising:

a third receiver for receiving third signals on the first communication channel from a third sector antenna, wherein the third signals are modulated with data using the first modulation technique;

a third demodulator for demodulating the data from the third signals; and

a third modulator for re-modulating the demodulated data from the third signals into third re-modulated signals, wherein the third modulator uses the second modulation technique;

wherein the IF mixer further combines the third re-modulated signals with the first and second re-modulated signals into a combined signal.

* * * * *

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United States Patent [19]

Simon

[11] **Patent Number: 5,570,354**

[45] **Date of Patent: Oct. 29, 1996**

[54] **DEVICE FOR INCREASING THE FUNCTIONAL AREA OF A SYSTEM OF DIGITALLY OPERATING CORDLESS TELEPHONES**

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[73] Assignee: **ASCOM Business Systems AG**, Bellach, Switzerland

[21] Appl. No.: **490,785**

[22] Filed: **Jun. 15, 1995**

[30] **Foreign Application Priority Data**

Jun. 16, 1994 [CH] Switzerland 01898/94

[51] **Int. Cl.**[6] **H04B 7/155**

[52] **U.S. Cl.** **370/26**; 370/29; 370/61; 370/97; 455/18; 455/54.1

[58] **Field of Search** 455/7, 15, 17, 455/18, 19, 53.1, 54.1; 370/26, 29, 30, 50, 55, 61, 75, 94.1, 95.3, 97, 85.13

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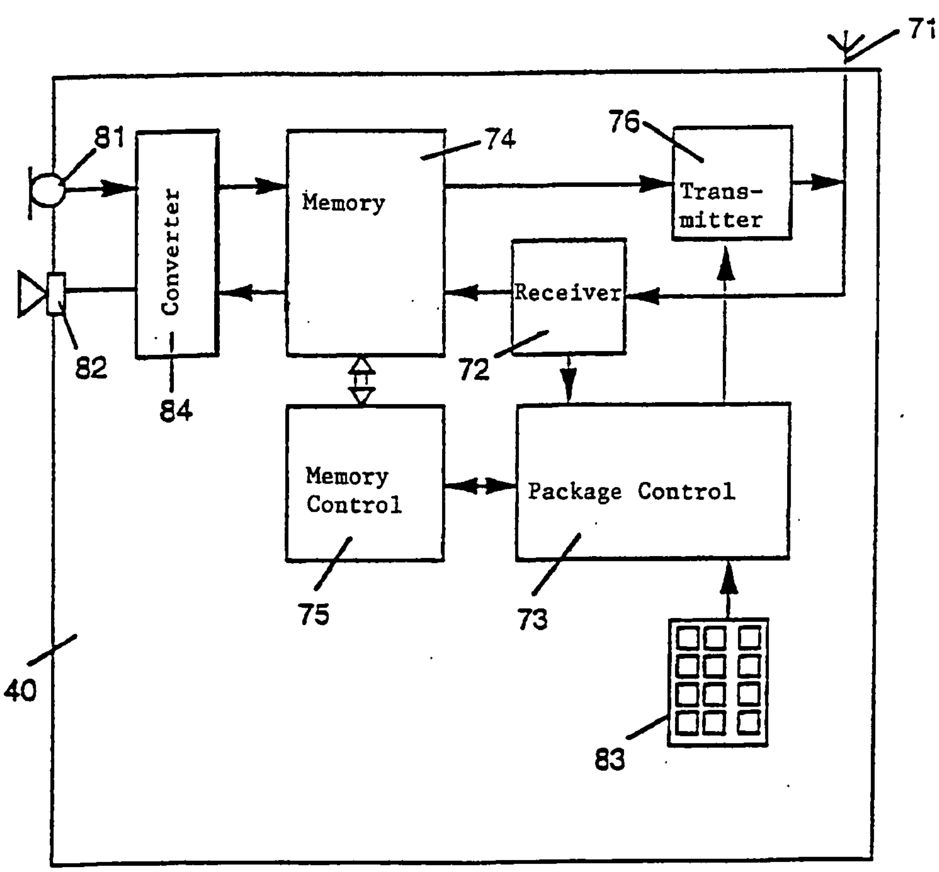
Primary Examiner—Benedict V. Safourek

[57] **ABSTRACT**

A system of digitally operating cordless telephone including a fixed station (20) connected with the common net (11) and several freely movable mobile stations (30.1 to 30.4). The naturally provided functional area (22) of the system can be enlarged by using a relay station (40). For this purpose the relay station (40) can permit the retransmission of transmission packages arriving from the fixed station (20) without changes to further mobile stations (30.5, 30.6) in a further functional area (23). In the other direction, the relay station (40) forwards respective packages arriving from the further mobile stations (30.5, 30.6) to the fixed station (20). For this purpose the relay station (40) maintains transmission channels, which are associated with each other in pairs and are chronologically very closely coupled, to the fixed station (20) as well as to the further mobile stations (30.5, 30.6) in accordance with the DECT Standards (Digital European Cordless Telecommunications).

7 Claims, 3 Drawing Sheets



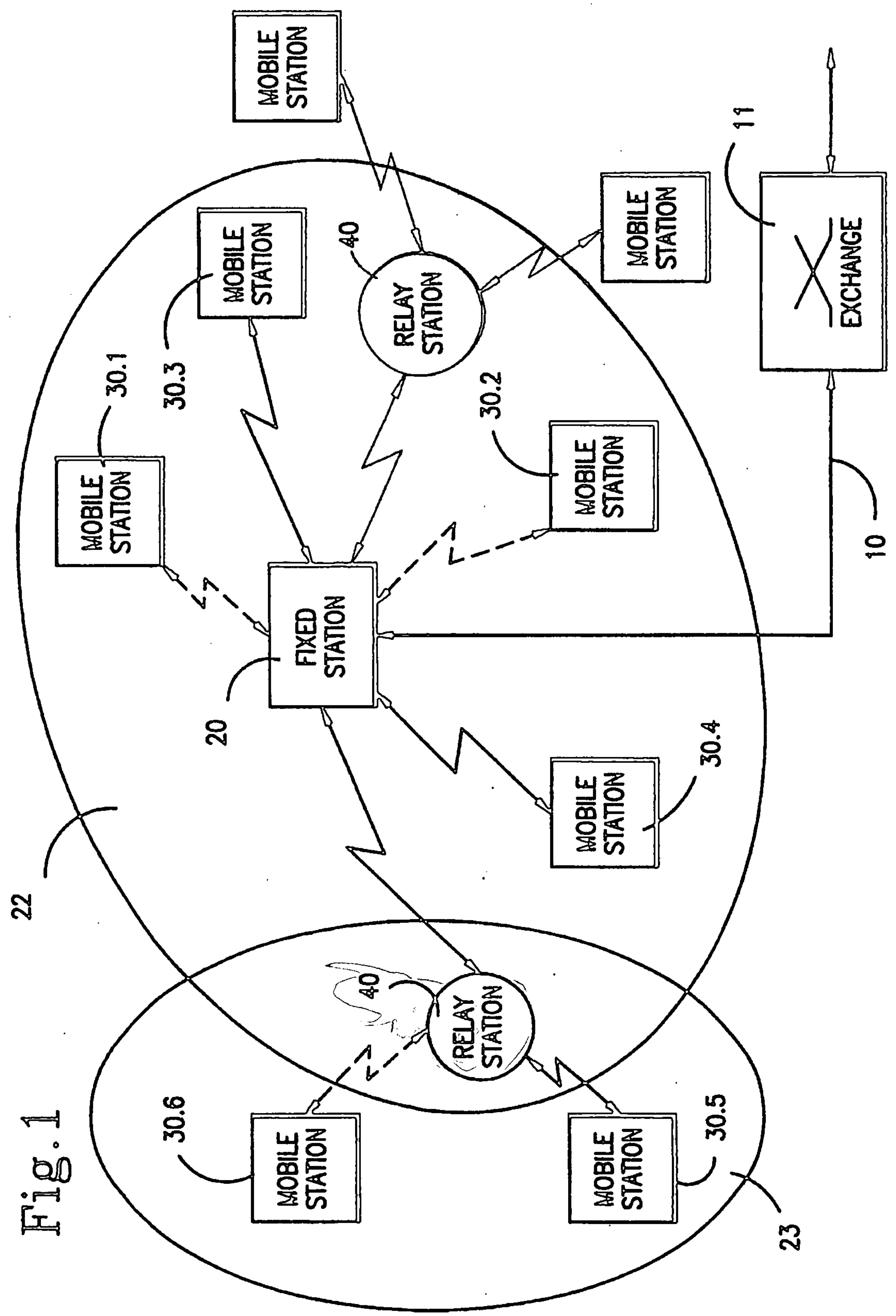

MOBILE STATION
MOBILE STATION
RELAY STATION
MOBILE STATION
EXCHANGE
MOBILE STATION
MOBILE STATION
FIXED STATION
MOBILE STATION
RELAY STATION
MOBILE STATION
MOBILE STATION
10
11
20
22
23
30.1
30.2
30.3
30.4
30.5
30.6
40
40

Fig. 1

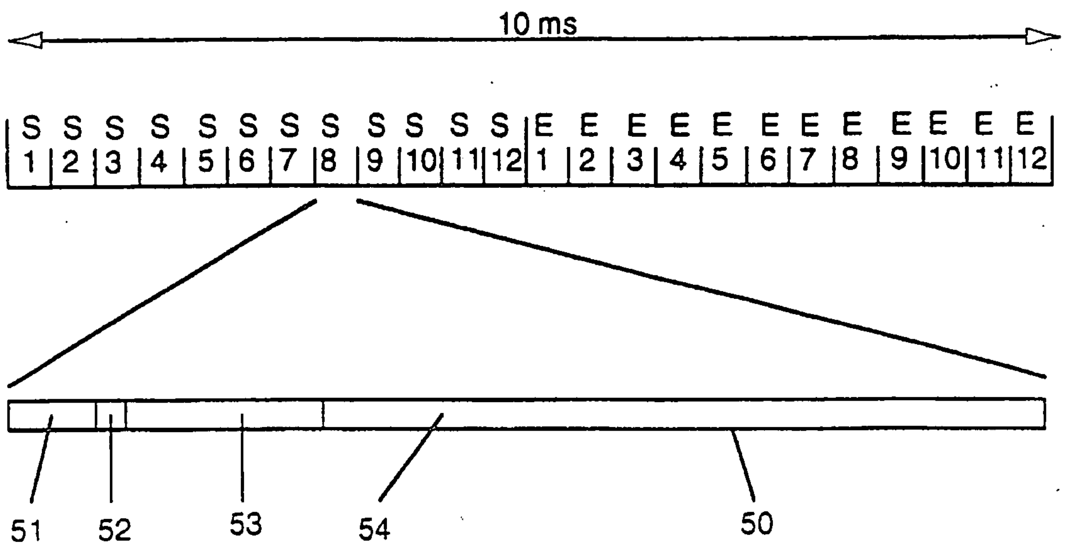

10 ms
S S S S S S S S S S S S E E E E E E E E E E E E
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
51
52
53
54
50

Fig. 2

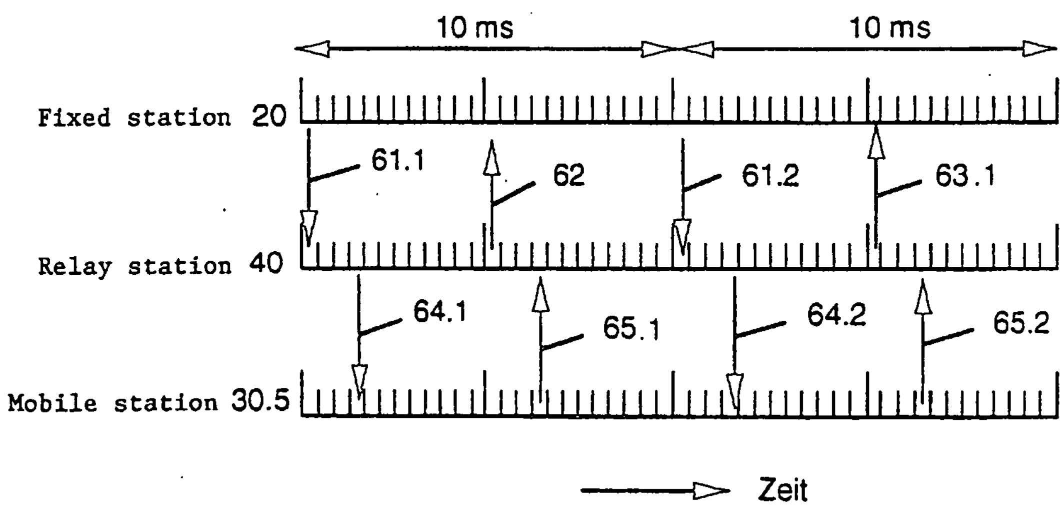

10 ms
10 ms
Fixed station 20
61.1
62
61.2
63.1
Relay station 40
64.1
65.1
64.2
65.2
Mobile station 30.5
Zeit

Fig. 3

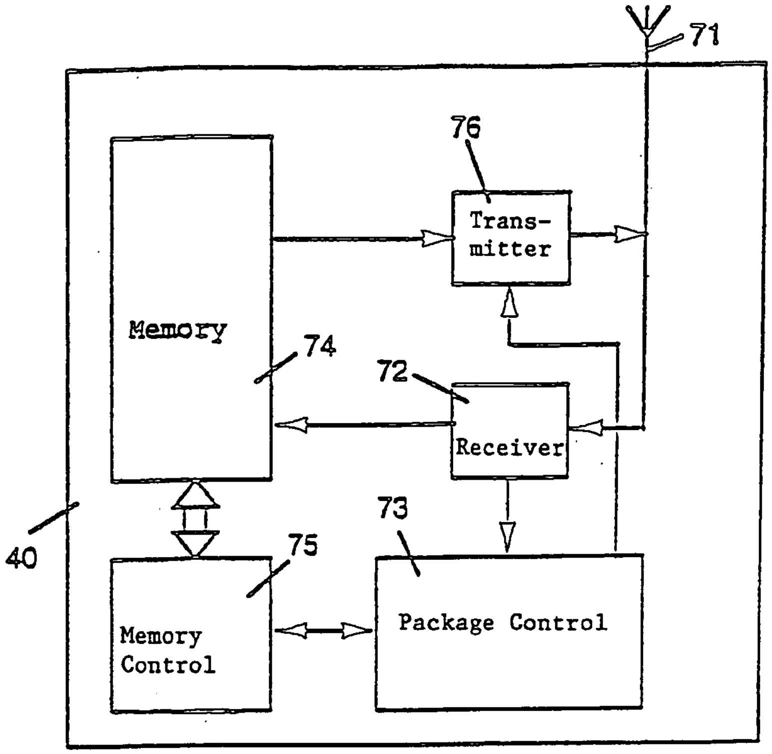

71
76
Trans-
mitter
Memory
74
72
Receiver
73
40
75
Memory
Control
Package Control

Fig. 4

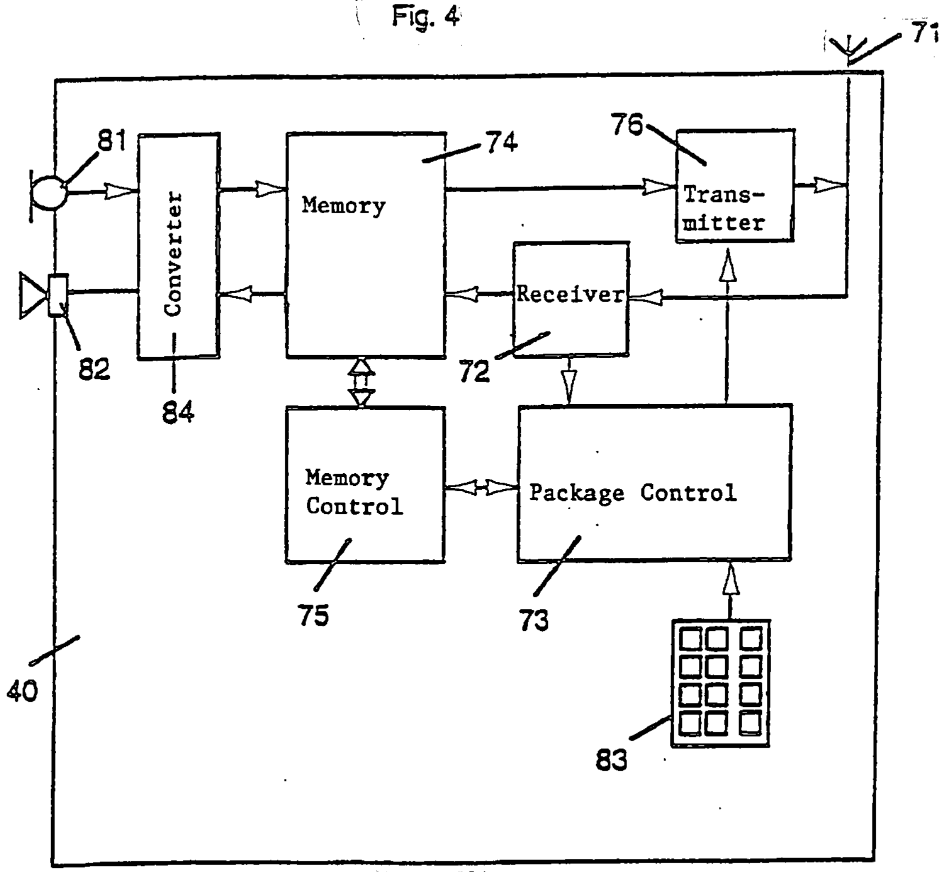

71
81
74
76
Converter
Memory
Trans-
mitter
Receiver
82
84
72
Memory
Control
Package Control
75
73
40
83

Fig. 5

DEVICE FOR INCREASING THE FUNCTIONAL AREA OF A SYSTEM OF DIGITALLY OPERATING CORDLESS TELEPHONES

FIELD OF THE INVENTION

The invention relates to a device for increasing the functional area of a system of digitally operating cordless telephones with a fixed station and with portable mobile stations associated with this fixed station, wherein the fixed stations and the respectively active mobile stations are connected via channels realized by means of time-multiplexing packages and several selectable transmitting frequencies in accordance with DECT Standards. The invention also relates to a method for operating such a device.

BACKGROUND OF THE INVENTION

Systems of digitally operating cordless telephones are known. For example, reference EP-A-0 399 611 describes such a system with a few primary stations connected to the common net and a plurality of mobile secondary stations. In accordance with the DECT Standards (Digital European Cordless Telephone), one duplex channel is respectively available to one primary and one secondary station for digital speech transmission. This duplex channel is allocated, time-multiplexed with eleven other duplex channels, to the respective connection between the said stations on a case to case basis. It is now possible to allocate one or even several free channels to a desired data connection for the transmission of data. This permits a correspondingly more rapid transmission. The stations have lists for the management of the channels which respectively indicate which channels are available for the mentioned purpose of data transmission.

In the field of telecommunications it has also been long known to employ relay stations in transmission arrangements in case where the required range exceeds the capabilities of the primary transmitter and/or the receivers. Such relay station regenerate the signals to be transmitted and transmit the regenerated signals on a respectively further transmission route or to a transmitting area to be supplied by the relay station and extended in respect to the primary area.

The ranges of digital cordless telephones are generally shorter than those of corresponding, analogously operating telephones. This represents a disadvantage of digital cordless telephones which limits their practical use.

OBJECT AND SUMMARY OF THE INVENTION

It is therefore the object of the present invention to correct this disadvantage.

The invention will be described in detail by way of example by means of five drawings figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of a system of cordless telephone,

FIG. 2 is a diagram to explain the DECT Standards,

FIG. 3 is a diagram to explain the device in accordance with the invention,

FIG. 4 is a block diagram of a relay station,

FIG. 5 is a further block diagram of a relay station.

DETAILED DESCRIPTION

FIG. 1 represents the diagram of a system of cordless telephones. This system comprises, for example, a single fixed or base station **20** which is connected via a telephone line **10** with the general telephone network. This network is represented by an exchange **11**. The system furthermore comprises a plurality of portable mobile stations or handsets, for example six mobile stations **30.1** to **30.6**. The mobile stations **30.1** to **30.4** and the fixed station **20** are located within a (first) functional area **22**, for example a building, within which they can communicate with each other. However, the mobile stations **30.5** and **30.6** are located within a second functional area **23**, for example an annex, from where they can communicate only on a limited basis or not at all with the fixed station **20**.

A relay station **40** is located at the edge of the first functional area **22**. This relay station as well as the mobile stations **30.1** to **30.4** lie, as described, inside the effective range of the fixed station **20** and are connected with it by radio. This is represented by bent two-headed arrows, wherein established voice connections are represented by solid arrows and potential voice connections by dashed arrows.

The mobile stations **30.5**, **30.6** are located inside the second functional area **23** and within the range of the relay station **40**. They are connected by radio with this station **40**. This has also been represented by solid or dashed arrows. Thus the relay station **40** is in simultaneous radio contact with the fixed station **20** as well as the mobile stations **30.5** and **30.6**.

FIG. 2 shows the diagram corresponding to the DECT Standards for the transmission between the stations **20** and **30**. Twenty-four time slots follow each other in repetition cycles of 10 milliseconds. The first twelve of these (**S1** to **S12**) are intended for the first transmission direction and the second twelve (**E1** to **E12**) for the other transmission direction. A package **50** is associated with each time slot, which is comprised serially by a synchronizing portion **51**, characters **52** to specify the control data, actual control data **53** and the voice data **54** to be transmitted, i.e. the effective data. In this way the DECT method forms a special type of time-multiplex transmission, wherein each package **50** is transmitted on one of ten possible transmission frequencies.

Each connection corresponding to a solid arrow in FIG. **1** occupies two time slots Sn and En, associated in pairs with each other (n=1, 2, 3, . . . 12), wherein one or two transmission frequencies have been selected from the mentioned ten possible frequencies for transmission in the two directions. The combination of the two parameters of time slot pairs and transmission frequency(ies) is called a channel and permits a duplex voice connection. Which of the twelve possible channels is occupied in an individual case and which transmission frequencies are selected depends on the respective situation and is therefore open to a great extent. However, the control data **53** see to it that at no time two mobil stations **30** communicate simultaneously via a common channel with the associated fixed station **20**. The dashed arrows of FIG. **1** correspond to potential channels not occupied at the moment.

FIG. **3** again represents the diagram of FIG. **2**, but reduced to half size, with two period lengths of 10 milliseconds each and separate for the fixed station **20**, the relay station **40** and one of the mobile stations **30.5** or **30.6**. The time axis extends from left to right.

Since in principle each time slot can only be used for a single connection, a duplex channel between the fixed

station 20 and, for example, the mobile station 30.5 requires a total of two channels of the type described. In this case the first channel is used for the connection between the fixed station 20 and the relay station 40, the second channel for the connection between the relay station 40 and the mobile station 30.5. In the process the two time slots of each transmission direction as well as the transmission directions themselves must be in the correct chronological sequence. This requirement makes the distribution of the said time slots or the two channels to respectively two period lengths necessary.

As an example for clearer explanation of what has been said in the previous paragraph, FIG. 3 shows an arrow 61.1 on the left side, which symbolizes a connection package from the fixed station 20 to the relay station 40 in the first time slot S1 of the first period length. A (dashed) arrow 62 for the opposite direction in the thirteenth time slot should actually be associated with this arrow 61.1. Because of the described chronological sequence, the connecting package indicated by the dashed arrow 62 can only be transmitted in the next period length, i.e. delayed by one period length (arrow 63.1). Chronologically prior to this, i.e. in the selected example in the fourth time slot S4 of the first period length, the arrow 64.1 indicates a connection package from the relay station 40 to the mobile station 30.5, whose contents correspond to the package in accordance with the arrow 61.1. For the opposite direction, the arrow 65.1 in the sixteenth time slot E4 of the first period length corresponds to this connection package 64.1. Thus, for the one transmission direction the time slots S1 and S4 of the first period length are sequentially used, and for the other transmission direction sequentially the time slots E4 of the first period length and E1 of the second period length. The time delays occurring in this connection, i.e. for the one channel symbolized by the arrows 61.1 and 63.1, are effected and controlled by the relay station 40. The package transmissions, represented by the arrows 61.2, 64.2 and 65.2 in the second period length, are repeated in each period length. The arrow 63.2 falls into the third period length and therefore is no longer represented.

FIG. 4 shows a block diagram of the relay station 40. It comprises a single antenna 70 as a connecting link to the outside, i.e. the fixed station 20 and the mobile stations 30.5, 30.6. It maintains via this antenna respectively two coupled channels between the said stations 20, 30.5, 30.6 in the above described manner.

The relay station 40 furthermore comprises a receiver unit 72, a package control unit 73, a package memory 74 with an associated memory control 75 and a transmitter unit 76. The packages 50 arriving at different transmission frequencies via the antenna 70 are received by the receiver unit 72 and synchronized and read by the package control unit 73 regarding their character 52 and control data 53. Next, controlled by the memory control 75 the packages are read into the package memory 74 for intermediate storage and at the proper time read out again for the transmitter unit 76. The transmitter unit then causes the transmission via the antenna 70. In accordance with the function this means a paired combination of the above mentioned channels between the fixed station 20 and the relay station 40 as well as the channels between the relay station 40 and the mobile stations 30.5, 30.6 in the second functional area 23.

The further structure and mode of operation of the package control unit 73, the memory control 75 and the package memory 74 are such that each package 50 is stored for as short a time as possible and exactly assigned to the intended time slot. Controlled by the package control unit 73, the transmitter unit 76 selects the respectively correct transmission frequency for each departing package 50. Which time slots and which transmission frequencies are respectively selected as the channel is the result of the known method of the connection structure in accordance with the DECT Standards, which is not being addressed here.

Any write/read memory can be used in principle as the package memory 74, and advantageously a common processor control is used as the memory control 75 and package control unit 73.

Instead of operating in accordance with the exact DECT Standards, the described device can also operate in accordance with a more or less modified time multiplex method. Instead of redefining the channels from case to case, it is for example possible to provide fixed channels for the connection between the fixed station 20 and the relay station 40.

As indicated, the relay station 40 constitutes an independent unit, which normally requires only one net or power supply connection, but not a cable-connected connection with the telecommunications net. This simplifies installation. It is also possible to provide battery operation in place of a power supply connection, which further simplifies the installation.

FIG. 5 shows a variant of the block diagram of FIG. 4. As described, this variant comprises units 71 to 76 with unchanged functions. Added to this is a microphone or telephone transmitter 81, a loudspeaker or telephone receiver 82, a dial keyboard 83 and a converter 84. These additional units are used to provide the relay station 40 also with the functions of a mobile station 30 in addition to its described relay functions. In this connection the package control unit 73 continues to differentiate whether an incoming package 50 is destined for internal use or, as described above, is to be transmitted again for external use after intermediate storage. If the package 50 has been recognized as "internal", it is forwarded to the converter 84 via the memory 74. The converter digitally/analogously converts the contained voice data and forwards the result as a voice signal to the telephone receiver 82.

In the other direction, voice segments being created in the telephone transmitter 81 are digitized by the converter 84 and assigned to a package 50. This is transmitted via the memory 74, the transmitter unit 76 and the antenna 71. The keyboard 83 is used in the conventional manner to trigger known dial processes manually.

The device in accordance with FIG. 5 can be used as a mobile relay station 40 and/or as a mobile station 30. In its expense it is comparable to every one of these stations and therefore represents a cost-effective option for realization.

The first and the second functional areas 22 and 23 can be arranged next to each other without overlap. However, as represented in FIG. 1, the areas can also overlap. In this case it can be decided, for example on the basis of defined receiving strengths, whether a channel is to be installed directly or with the inclusion of the relay station 40.

It is of course possible to associate two or more relay stations 40 with one fixed station 20 in place of a single relay station 40, which serve independent localities which are located outside of the normal range between the fixed station 20 and the mobile stations 30, i.e. outside of the first functional area 22. Furthermore it is in principle possible to switch two or more relay stations 40 in series to bridge a longer distance. However, the latter has two important disadvantages. The first of these disadvantages lies in that additional channels are blocked by this which, in accordance with the DECT Standards, actually should be available for

separate connections. The other disadvantage results because of further delays in the additional relay stations **40**. This can cause greatly reduced transmission qualities, in particular because of interfering, chronologically stacked echoes of the words of the speaker and those coming from his party.

What is claimed is:

1. A device for increasing the functional area of a system of digitally operating cordless telephones with a fixed station and with portable mobile stations associated with said fixed station, wherein said fixed station and active ones of the mobile stations are connected via channels realized by means of time-multiplexing packages and several selectable transmitting frequencies in accordance with DECT Standards, wherein

at least one relay station is disposed at the edge of an area which corresponds to the actual functional area of the system, and wherein

each relay station includes a single antenna, a receiver unit succeeding the antenna and a package control unit for receiving and evaluating incoming packages arriving at said antenna, a package memory with an associated memory control for the controlled intermediate storage of all said incoming packages and further comprising a transmitter unit connected to the antenna for the successive, controlled retransmission of the packages stored in said memory.

2. A device in accordance with claim **1**, wherein

a single relay station is provided.

3. A device in accordance with claim **1**, wherein

two or more relay stations are provided, which operate parallel in respect to each other and are assigned to different localities.

4. A device in accordance with claim **1**, wherein

said relay station has an additional function provided by additionally providing a microphone capsule, a receiver capsule, a dial keyboard and a converter connected with the package memory, because of which units the relay station has the additional function of a mobile station.

5. A method for operating a device for increasing the functional area of a system of digitally operating cordless telephones with a fixed station and with portable mobile stations associated with this fixed station and with at least one relay station in accordance with claim **1**,

wherein each relay station maintains respectively one channel with the fixed station and a channel with those mobile stations which are located in the range of the relay station and outside of the area which corresponds to the actual functional area of the system,

wherein these channels for connecting the fixed station with the said mobile stations are combined in pairs by the relay station,

wherein the relay station supervises all said packages arriving on said channels and retransmits them in a controlled manner in such a way that in each channel pair the respective chronological sequence of the packages corresponds to the information flow and only a minimum time delay occurs,

wherein a channel, in accordance with the DETC Standards, consists of the combination of two time slots associated with each other and one or two of several transmission frequencies,

wherein all channels are different from each other, and

wherein each said time slot is occupied only once.

6. A method in accordance with claim **5**, wherein

the channels are set up and taken down as conditions demand.

7. A method in accordance with claim **5**, wherein

channels are fixedly established between the relay stations and the fixed station.

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